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ABSTRACT

The state-of-the-art of hardware technology for computers in education is discussed. The choices that are available to the user, and the questions the user must ask himself before making a choice of computer hardware, are explored. An example of the costs of a central computer system for educational use is presented. (Author)

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Hardware Technology for Computers in Education: One of the Soluble Problems

R.J. Seidel

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Based upon a presentation at a
Teaching Session of the
American Physiological Society
Atlantic City, N.J. April 1973

HUMAN RESOURCES RESEARCH ORGANIZATION
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16. Abstracts

This paper is a discussion of the state-of-the-art of hardware technology for computers in education. The choices that are available to the user, and the questions the user must ask himself before making a choice of computer hardware are discussed. An example of the costs of a central computer system for educational use is presented.

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Prefatory Note

This paper is an adaptation of a presentation by Dr. Robert J. Seidel, HumRRO Division No. 1 (System Operations), Alexandria, Va. The presentation, titled "Hardware From a User's Point of View," was made at the Teaching Session of the American Physiological Society program, which was held in conjunction with the Federation of American Societies of Experimental Biology meetings in Atlantic City, N.J., April 1973. The title of the session was "Computer Assisted Education." Dr. Seidel's presentation was made in Part II: Challenges of CAE Development. The entire proceedings can be found in *The Physiologist*, vol. 16, no. 4, November 1973, pp. 594-683.

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HARDWARE TECHNOLOGY FOR COMPUTERS IN EDUCATION: ONE OF THE SOLUBLE PROBLEMS

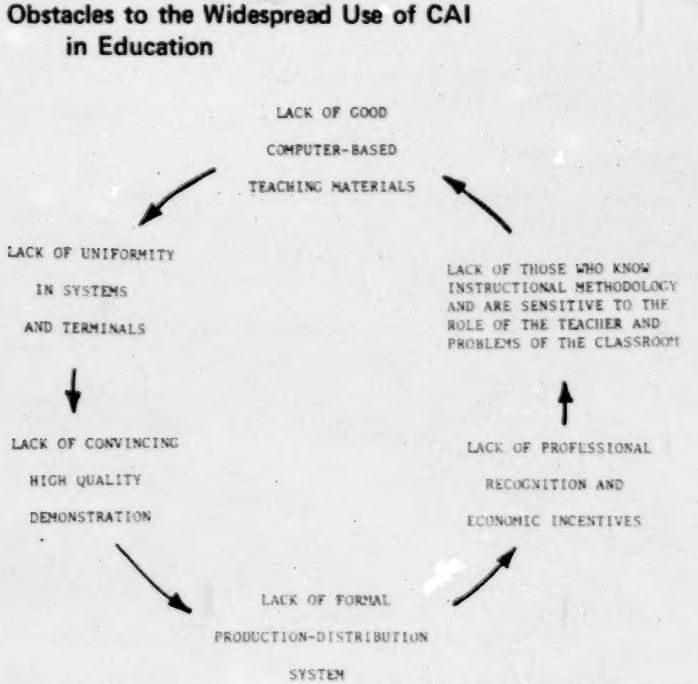
R.J. Seidel

Introduction[1]

In Part I of this Teaching Session on Computer Assisted Education, Dr. Tidball provided background in computer fundamentals. He stressed the gains in speed made by the digital computer in its four generations of development, its precision, and its storage capabilities, and briefly described how the digital computer operates.

Dr. Tennyson then discussed the applications of computers in education, both the direct educational support (using the computer in an instructional environment) and the indirect support (using the computer as an additional resource in noninstructional activities).

In his introduction to this section, "Challenges of CAE Development," Dr. Tidball's illustration summarizing the obstacles to widespread CAI use is a useful takeoff point for a discussion of hardware as a potential problem area for computer usage in education (see Figure 1). Nowhere is hardware cited as a primary issue. The significance for us is that


Obstacles to the Widespread Use of CAI in Education
LACK OF GOOD COMPUTER-BASED TEACHING MATERIALS
LACK OF UNIFORMITY IN SYSTEMS AND TERMINALS
LACK OF THOSE WHO KNOW INSTRUCTIONAL METHODOLOGY AND ARE SENSITIVE TO THE ROLE OF THE TEACHER AND PROBLEMS OF THE CLASSROOM
LACK OF CONVINCING HIGH QUALITY DEMONSTRATION
LACK OF PROFESSIONAL RECOGNITION AND ECONOMIC INCENTIVES
LACK OF FORMAL PRODUCTION-DISTRIBUTION SYSTEM

Note: Adapted from Anastasio and Morgan (1) and reproduced in *The Physiologist*, vol. 16, no. 4, November 1973, p. 609.

Figure 1

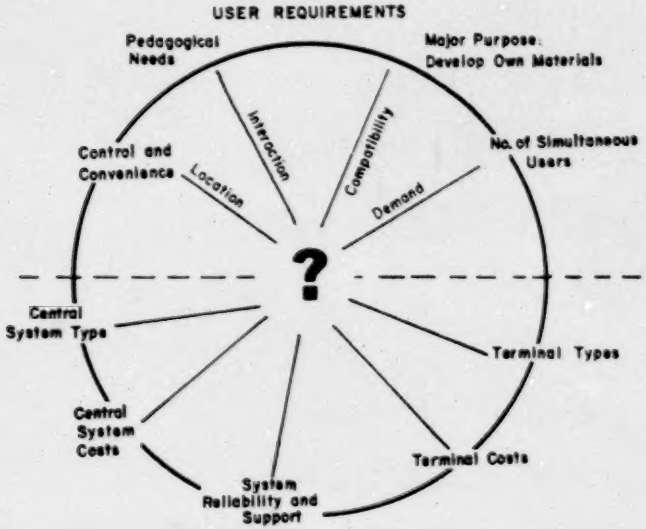
[1] Charles S. Tidball is from The George Washington University Medical Center, and Robert D. Tennyson from Florida State University. Other speakers in Part II of the Teaching Session were G. Octo Barnett, Massachusetts General Hospital, and Harold Wooster, National Library of Medicine.

problems existing in the field of computers in education are really much more systemic in nature than they are based upon a particular technology that has been available for some time. I can sympathize with those who would like to see analog computers used. However, I think that, while there is a need for this kind of capability, we are probably a lot farther along in the field of hardware than we are in dealing with any of the other systemic related problems in the field of computers in education. Dr. Tennyson summarized some of the factors that are involved in considering the use of computers, such as initial costs, software developments, and other users.

The basic theme of my presentation can be expressed in a single sentence—there is no particular, absolute answer to the choice of hardware or the use of computers in education. A person, or institution, wishing to enter the field of computers in education must ask himself a number of questions, and this is what I would like to discuss.

What are the questions that you have to ask yourself? They relate to how you want to take advantage of the computers to amplify the quality of the instructional environment. Generally, the questions can be grouped into two categories: user requirements and facilities considerations. The fact that there are a number of contingent issues to be considered, but no necessary order in which they must be taken, is illustrated in Figure 2. Thus, you can start with any specific category and move around the circle, making certain that no category is neglected. In addition, you, the user, must establish the relative importance of the questions.

A Potpourri of Decisions for the Potential Educational User of Computers



Note: In *The Physiologist*, vol. 16, no. 4, November 1973, p. 611.

Figure 2

COMPUTER SYSTEM COMPONENTS

To review the components of the computer system discussed earlier by Dr. Tidball, I want to consider their nature and where they are located. Taken together, these issues are relevant to the degree of control you have over your own technological base. Your decision is relevant to the cost of using the technology and to the availability and priority of the system for you.

First, the *central processing units* (CPUs) are the main capabilities for arithmetic operation. *Core storage* provides the capability of executing programs—this is called "fast core." *Secondary storage*, consisting of drums or other devices, is slower in nature (additional auxiliary storage disc units) for storing the instructional materials and support routines not as frequently accessed. In addition, all sorts of peripheral equipment (tapes, printers, and other input/output devices such as terminals) round out the system.

COSTS OF CENTRAL SYSTEM

Levien (1972, pp. 470-473) provides a good illustration of cost allocations in terms of central system components. A large system (an IBM 370 maxi computer) might yield the support required for 1,000 simultaneous users at a total monthly rental of approximately $390,000. With roughly 1,000 potential simultaneous users at 75% average utilization, 750 students per hour can be programmed on-line. With the system in use 300 hours each month, every month of the year, there are approximately 225,000 student hours of instruction per month. The hardware cost, therefore, would be something like $1.39 (plus 35 cents per hour operating costs) per student contact hour. Projecting into the next 10 years (following the Levien example), a 44% reduction every four years in operating costs, coupled with a 33% *annual* reduction in the price of computers, reduces the central hardware cost (based upon CPU, storage, and peripherals), even in the most conservative estimates, to approximately four to five cents per student hour (Levien estimates two to three cents per student hour). This one example, taken in detail, suggests that, with increasing numbers of simultaneous users and large numbers of hours of use per month, the central hardware costs will play a very minor role in functional system costs in the 1980s.

Now what about the other aspects of computer hardware—for example, the peripherals? The peripherals in CAI refer to the terminals, the input/output devices. Frequently the selection made is based upon familiarity with one or two devices, with too little thought given to the instructional needs of the application as a criterion. Despite the fact that teletypes make a poor graphic terminal, they are often chosen because they may be the most readily available type of terminal, or because the decision makers have not seen them in operation. Also, they are rather inexpensive compared to other terminals; you can purchase one for as little as $500 (e.g., a used model 33 teletype). The point is, however, that terminal technology has advanced beyond the state where you can be satisfied with a line-by-line, very slow, presentation device. There are a number of graphic capabilities available through inexpensive digital-type plotters, video terminals, vector CRTs, and so forth. It seems the potential for instructional applications that combine both graphic and alphanumeric material is often overlooked because of the belief that a graphic capability is beyond the means of a particular user. There are a number of different types of graphic displays, and they can be purchased today from around $5,000 to $8,000. A few years ago the cheapest graphic terminal cost well over $10,000.

COMMUNICATING WITH THE SYSTEM

One of the areas that deserves much more consideration is the means provided the user to communicate with the system. When the means of communications is awkward and artificial, the user's interest dwindles. In physics, for example, there are a large number of symbols and common notation requirements. It's unnatural that a physics student is not allowed to use the notation while interacting with the computer. Some terminals, such as the IMLAC or Anagraph terminals, have programmable keys, allowing individualized character sets. Many terminals have the capability of assigning special functions to particular keys, and a single key can generate the mathematical operation, such as a matrix inversion.

There are other capabilities like a touch panel, which is both an exciting means of communication and a rather easy means of indicating the choice by the student. The terminal of the Plato IV system at the University of Illinois has such a feature. The creation of line drawings by an engineering student can be a somewhat tedious task when all the coordinate points have to be specified, but by using a light pen or other kind of pointing device the student can draw the image directly on the face of the screen. Pedagogically, if the student's input is long and time consuming in proportion to the output that he receives from the system, much of the student's attraction to that computer is lost. The significance is that a readily available standard keyboard design may be inadequate for many types of instructional usage. You should not immediately and meekly accept the keyboard as given by the vendor—clearly, there are variations available.

The output capability of the terminal mentioned earlier is just as important to the educational process as the input communication channels. You can integrate and should, in many cases, specify audio output. This was, at one time, integrated into the Model 33 teletype at Stanford to give instructions to children who did not read. In medical application, where students are learning to interpret X-rays, the ability to superimpose alphanumeric output and line data on the X-ray itself is beneficial to the learning process. I think you will find that there are terminals available to provide this capability today. With the demonstration of the CHARGE terminal that we brought with us, you will see some possibilities for advanced generative graphics to allow not only line graphics, but also actual color and surface graphics. This illustrates the state-of-the art as it is now.

SYSTEM RELIABILITY AND SUPPORT

A host of questions relate to system reliability and support.[1] Does the vendor provide a program of continued development and support? What instructional language and operating system support the computer? Have other users, students and faculty, had experience with the system? What has been their reaction? Are local and teleprocessing capabilities available? Is the system one of a kind or is it a standard brand?

MAKING USER DECISIONS

These are the capabilities that are available to you—but you must make the user decisions. What are your requirements? Where should the capabilities be located? How much of the central system should be near you? How much would you be willing to surrender to somebody else? This depends upon your purposes for the use of these terminals and this system. In other words, you *can* go to a commerical time-sharing

[1] Adapted from personal communication with Dr. Harvey Long.

system. You *can* get in for as little as $600 a month and have the terminal at your disposal 24 hours a day (e.g., TYMSHARE, Inc.). The type of terminal, generally speaking, is a teletype. You will not have control over the kinds of materials that exist except what is in the library of the time-sharing system. You may be able to contribute your own development, but that would require another arrangement. On the other hand, you can go to an on-site system, such as the type I described earlier, which, as noted, could go as high as $390,000. You could obtain a smaller system that might cost you about $50,000 a month. The question that then arises is, if it is on-site, should you share the system with administrative and research users? Or are you going to require it be dedicated to instructional purposes? In turn, what are the relevant dimensions for deciding this?

First you might ask such questions as:

Are you going to be using programs developed by people outside of your institution most of the time?

Or, are you primarily going to develop and use your own programs?

Or, are you going to plan for mass dissemination of your materials for other people's use? (This clearly is going to demand that you consider the compatibility of your own hardware system, and whether it is a standard system.)

Do you have the available staff to produce the materials and to maintain and operate the system? (Therefore, you have to consider the educational and the technical skills available and those required of your staff.)

Next, consider the cost as I indicated earlier. If you go to the time-sharing system, you must pay a line charge portion, plus the cost of the terminal leasing. If you have a local system, you have to share the CPU costs, as well as the terminals and possibly line cost depending upon your location relative to that of the central system, even if it is in your own school. How many simultaneous users are going to be required on this system? Clearly, it is advantageous to distribute the cost as broadly as possible, but how many do you require? Whether authors will be able to use the system simultaneously with students is another consideration, because your system will differ accordingly. Will you be in a research environment where you can tolerate high costs?

With regard to the training of physicians, we are all concerned with more than the cost of the system at the point in time of training. More important, what is the criticality of a graduate's making an error subsequently in practice, and how do you evaluate it in terms of the cost of the training that you provided him? Insurance companies have for years used actuarial tables to place values on specific injuries, but I know of no one in education who has attempted to make analogous estimates. It's an interesting kind of dollar figure for someone to determine.

It is true, in any event, that graduate or professional training is among the most expensive, and if there is a place where use of the computer in education can indeed be cost effective, it is at that level today. We at HumRRO estimated a few years ago (Kopstein and Seidel, 1968) anywhere between $2.75 to $5.00 or $10.00 per student hour in traditional instruction, dependent upon the type of professional school. Based on our earlier estimates, computerized instruction is available for as low as $3.00—or even $2.75 per student hour, easily competitive if there are a large number of student contact hours on that particular system. Projections are being made for 50¢ to $1.00 per student hour (TICCIT or PLATO IV), but these figures are not yet a reality. At an undergraduate level of instruction, Bunderson (1970) has estimated $2.00 per student hour for a complete tutorial CAI course. Bunderson's estimates were based upon 1,500 students sharing a 32-terminal system (IBM 1500). Jamison, *et al.* (1970) with a drill-and-practice usage in elementary schools, derived empirical costs of $3.40 per contact hour (192 terminals, RCA system).

If system costs are clarified, what kind of control do you want over the system? Is it necessary or desirable for you to have control over the entire system? How much priority availability of resources do you want? What is the critical convenience level for you to say, "I'm going to use that system because it's available to me at any time, the terminal is in my office, I like it, it's easy to use, etc?"

You as the developer, on the one hand, may say, "I'd like to have one in my office that I can get to any time I want." You as the administrative decision maker, however, see the dollar signs clicking away and therefore want maximum utilization of that computer, because only when there is increased utilization do you lower the cost per contact hour. Thus, there is a trade-off in system cost/performance between the cost per student hour, or per user hour, the number of simultaneous users and the critical convenience level to a department that may have special needs for tailoring the materials, or for having access, and so forth.

Having made the agonizing decisions on critical convenience and system costs, you might address the questions of system requirements from a pedagogical point of view. If you don't have a need for graphic capability, a teletype (which yields a line-by-line presentation) might suffice. On an inquiry basis (i.e., where the student or the author can make more of a broad-scale, natural language inquiry into the system—conduct dialogues with it) you will have a great many system requirements for storage, system and language software, flexible and rapid terminal device, and so forth. At this point you may wish to recheck your computer vendor's support packages. Possibly, some drill-and-practice segments won't demand that much capability for you—where you augment a particular course with some segments of skill maintenance. For example, if it's simply a matter of having the student learn terminology in a cost-effective way, you could easily use a teletype. On the other hand, you may want a full-blown, interactive tutorial for an entire course of instruction and other system requirements become important (time sharing, data management, complex files). A comprehensive central system is needed to enable the managing of branching requirements, record updating, and so forth, within that tutorial system. The requirements for simulations are also unique and different. Here a graphic capability could be most useful, especially in the medical field in the examination of anatomical and neurophysiological relationships.

In short, you the user must decide: How does the simulation, how does the drill and practice, how does the tutorial, how does the inquiry, fit into your pedagogical scheme? Then you can determine the capabilities and constraints of particular hardware and software that will support it satisfactorily. The computer technology is available, choice of a particular vendor's computer will give you certain language and system software. It's a question of purposes, which only the instructional designer, the administrator, and student users can answer.

NETWORKING

Lastly, I wish to address the concept of networking. Networking can provide the user with the capability for sharing resources not possessed locally. Applied to instructional needs, it enables the teacher or the student to access a widespread library of courses and support programs that may be available elsewhere. Where you don't have all the needed capabilities on campus, you can augment those you have by going to other institutions—this lowers your costs, although you surrender some control. Also, forming cooperative groups—the kinds of user capabilities—on a superinstitutional basis can do wonders for enhancing the discipline identification and, in turn, discipline-oriented curricular developments. Thus, embryologists at one school of medicine can talk to

embryologists at another school. On a national scale you can then pool your resources and create important masses of personnel resources and facilities to further curriculum reform.[1]

The most far-reaching implications for national networking are in broad areas of educational system reform. Networks can provide virtually an alternative learning system, making possible a major step toward the implementation of personally relevant instruction. In medicine, for example, a nationwide learning resource pool could be developed, so that a student could have access to a library of courses not available at his particular institution. The student could obtain education on demand. This concept has the possibility of becoming a reality.

In summary, the recent advances in computer hardware (and software) are adequate to support a wide range of learning experiences. At the present stage of educational technology, the real concerns are for educators to consider required and desirable user arrangements whereby the technical capabilities that are available can be made useful for learning and development activities of students, faculty members, and administrative decision makers.

[1] Harold Wooster, "The Lister Hill Experimental CAI Network—A Progress Report," *The Physiologist*, vol. 16, no. 4, November 1973, pp. 626-630.

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